

Automated information system for analysis and prediction of production situations in blast furnace plant

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Abstract. Advances in modern science and technology are inherently connected with the development, implementation, and widespread use of computer systems based on mathematical modeling. Algorithms and computer systems are gaining practical significance solving a range of process tasks in metallurgy of MES-level (Manufacturing Execution Systems – systems controlling industrial process) of modern automated information systems at the largest iron and steel enterprises in Russia. This fact determines the necessity to develop information-modeling systems based on mathematical models that will take into account the physics of the process, the basics of heat and mass exchange, the laws of energy conservation, and also the peculiarities of the impact of technological and standard characteristics of raw materials on the manufacturing process data. Special attention in this set of operations for metallurgic production is devoted to blast-furnace production, as it consumes the greatest amount of energy, up to 50% of the fuel used in ferrous metallurgy. The paper deals with the requirements, structure and architecture of BF Process Engineer's Automated Workstation (AWS), a computer decision support system of MES Level implemented in the ICS of the Blast Furnace Plant at Magnitogorsk Iron and Steel Works. It presents a brief description of main model subsystems as well as assumptions made in the process of mathematical modelling. Application of the developed system allows the engineering and process staff to analyze online production situations in the blast furnace plant, to solve a number of process tasks related to control of heat, gas dynamics and slag conditions of blast-furnace smelting as well as to calculate the optimal composition of blast-furnace slag, which eventually results in increasing technical and economic performance of blast-furnace production.

1. Introduction

The modern trend of science and technology development is characterized by development, implementation and wide application of computer decision support systems in the Industrial Control System (ICS) based on the methods of mathematical modelling [1–5]. At present the role of algorithms and computer programs is becoming more and more evident for solving a complex of process tasks in metallurgy at MES Level (Manufacturing Execution Systems are industrial process control systems) of modern automated information systems at the largest iron and steel works in Russia [1, 2].

This determines the requirement for development of simulation systems based on a set of mathematical models considering the physics of the process, fundamentals of heat and mass transfer, energy conservation laws as well as special influence of process and standard characteristics of raw materials upon production process data. A special place in this complex of metallurgical production



processes is taken by blast furnace production as the most energy-intensive production with its share of the fuel used in ferrous metallurgy up to 50%.

The authors have developed and implemented an automated information system for analysis and prediction of production situations in the blast furnace plant (AIS APPS BFP) of Magnitogorsk Iron and Steel Works.

2. System structure

The structure of the automated information system for analysis and prediction of production situations in the blast furnace plant is shown in Figure 1. Its main subsystems are as follows:

- “Data Acquisition and Storage” which fills the database with actual reported performance parameters of blast furnace production;
- “Visualization of Shift and Daily Average Data of Blast Furnace Operation” which forms graphic trends as per parameters chosen by the user in any combination for the specified period of time;
- “Preparation of Technical Report on Operation of Blast Furnaces and Blast Furnace Plant” which is designed for making a technical report on operation of blast furnaces and blast furnace plant in whole for the specified periods of operation;
- “Comparison of Reported Performance Parameters of Blast Furnaces and Blast Furnace Plant” which gives an opportunity to compare the performance parameters of the plant or furnace by a set of chosen parameters for the specified period of time;
- “Model-based Decision Support, Prediction of Process Situations and Diagnostics of Blast Furnace Operation”. Implementation of the subsystem is based on calculation algorithms with the use of mathematical models of the blast furnace process for the period of operation of individual blast furnaces or the plant in whole as chosen by the user. The analysis of the blast furnace process makes it possible to ascertain that this subsystem shall include the following interconnected subsystems of a lower stratum: heat-and-mass balance calculations of blast furnace smelting; slag conditions; gas dynamic conditions; heat conditions; optimal distribution of fuel and energy resources; optimal selection of the burden composition as well as diagnostics of blast furnace smelting operation. Each of these subsystems interacts with other parameter blocks, subsystems and environment;
- “Visualization of Performance Parameters of Blast Furnace Production for OLAP” which provides authorized users with access to all reported data on blast furnace production in the company’s corporate network.

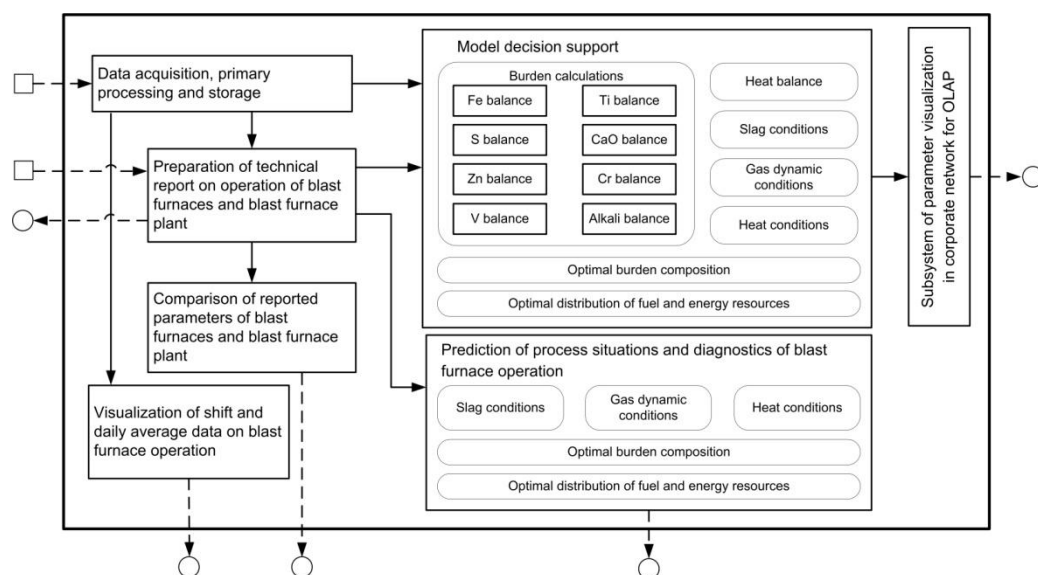




Figure 1. Structure of automated information system for analysis and prediction of production situations in blast furnace plant: –  data source; –  data presentation.

3. System engineering and implementation

In the course of system engineering a detailed development of functionality was required for individual subsystems. For this purpose the generalized functional model was developed on the basis of ideas and notations of IDEF0 (Integrated computer aided manufacturing DEFinition) Structured Analysis and Design Methodology [6]. It was implemented in AllFusion Process Modeler (BPwin). The use of this methodology has made it possible to create functional blocks of individual subsystems, to reveal actions performed by them and connections between these actions, controlling actions and execution mechanisms of each function. The total number of decomposed blocks of the functional model of AIS APPS BFP is 152. Decomposition of the model was performed up to and including the third stratum.

Analyzing the requests made by process staff, reference data of blast furnace production and functional modelling, mathematical and algorithmic software was developed and taken as a basis for software implementation of the subsystem displaying data on operation of individual blast furnaces and the plant in whole. The structured system analysis and engineering of mathematical model blocks were performed on the basis of the procedure-oriented approach. The basis of this approach is the use of data flow diagrams (DFD), an entity-relationship model where the main components are data flows transferring information from one module to another [6]. The notation of the DFD method involves breaking of the mathematical model into separate functional components (processes) and their presentation as a network interconnected by data flows.

4. Software components of the system

The software implementation of AIS APPS BFP – an integrated software complex for BF Process Engineer's Automated Workstation – has been made in Microsoft Visual Studio (C# Programming Language) [7]. Figure 2 shows the main components of the software architecture. The central link is the data storage structure [8] which is formed on the database server of the information computer center of blast furnace production. Its sources are hardware and software of the blast furnace plant ICS, corporate information system (CIS) and central control room (CCR) of the factory. Depending on the requirements of individual subsystems, it is possible to implement various periods of data averaging in the base using mechanisms of the database management system

The architecture shown in Figure 2 provides the required functionality, fulfilment of subject area requirements, relatively simple system extension and changes, possibility of free-running implementation of separate software modules and their independence from the data storage structure.

The list of the design software modules is as follows:

- “Heat Balance of Blast Furnace Smelting” makes automatic calculations and displays inputs and outputs of heat balance of blast furnace smelting on the basis of monthly average reported data on blast furnace plant operation for the period specified by the user;
- “Fe, S, Zn, Ti, CaO, Cr Mass Balances of Blast Furnaces” makes automatic calculations and displays mass balances of Fe, S, Zn, Ti, CaO, Cr in blast furnaces on the basis of monthly average reported data on blast furnace plant operation for the period specified by the user;
- “Gas Dynamic Conditions of Blast Furnace Smelting” makes automatic calculations and displays parameters of gas dynamic conditions of blast furnace smelting for the period specified by the user;
- “Slag Conditions of Blast Furnace Smelting” makes automatic calculations and displays parameters of slag conditions of blast furnace smelting on the basis of monthly average reported data on blast furnace plant operation for the period specified by the user;

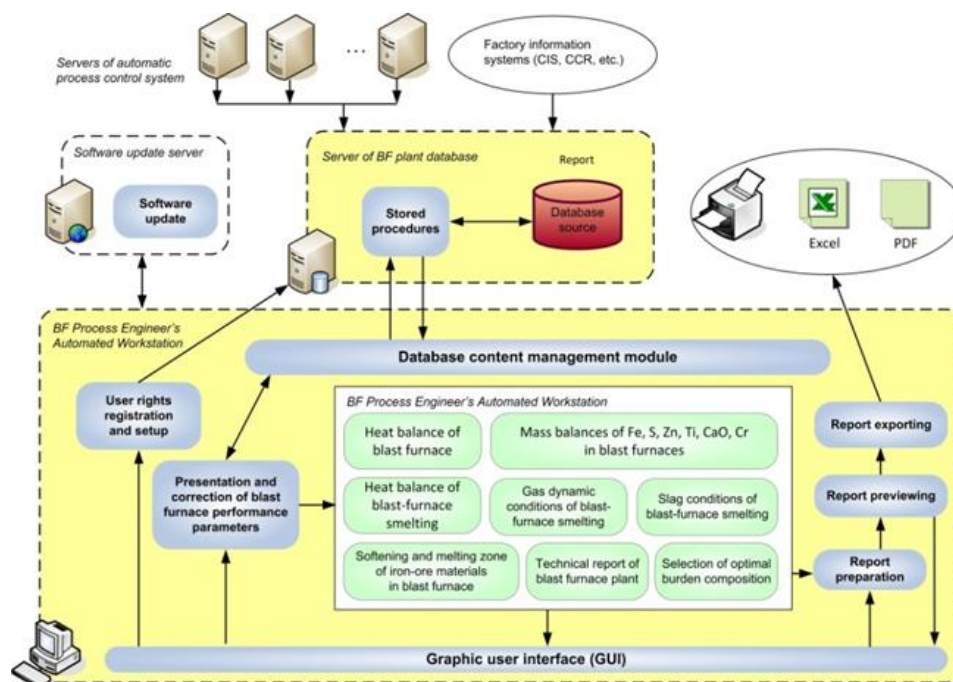


Figure 2. Architecture of software complex for BF Process Engineer's Automated Workstation.

- “Selection of Optimal Burden Composition” enables to solve process task related to selection of the optimal burden composition on the basis of monthly average reported data on blast furnace plant operation for the period specified by the user;
- “Softening and Melting Zone of Iron-Ore Materials in Blast Furnace” makes automatic calculations and displays parameters characterizing the shape and location of the softening and melting zone of iron-ore materials in the blast furnace on the basis of monthly average reported data on blast furnace plant operation for the period specified by the user;
- “Technical Report of Blast Furnace Plant” displays parameters of the technical report for a calendar month as well as from the beginning of the year to the month specified by the user.

The software complex is made as a separate client application installed on the user's computer by installation of the load file. After the user's registration in the software and loading of the main form the screen will display the reported data for the base period (actual reported calendar month) of blast furnace operation which are automatically retrieved from the database of MMK's ICS center for the calendar month (Figure 3). Data display in the main form is possible for two periods: base and comparative. The comparative period is used for comparison of actual reported performance parameters of blast furnace operation with analogous parameters in the base period for the calendar month. The complex has a wide selection of interactive settings for the user's improved readability and minimized routine actions. The results of the model reports are presented in the tabular and graphic user forms. Preparation of the report with the possibility of its previewing and exporting in other formats is provided.

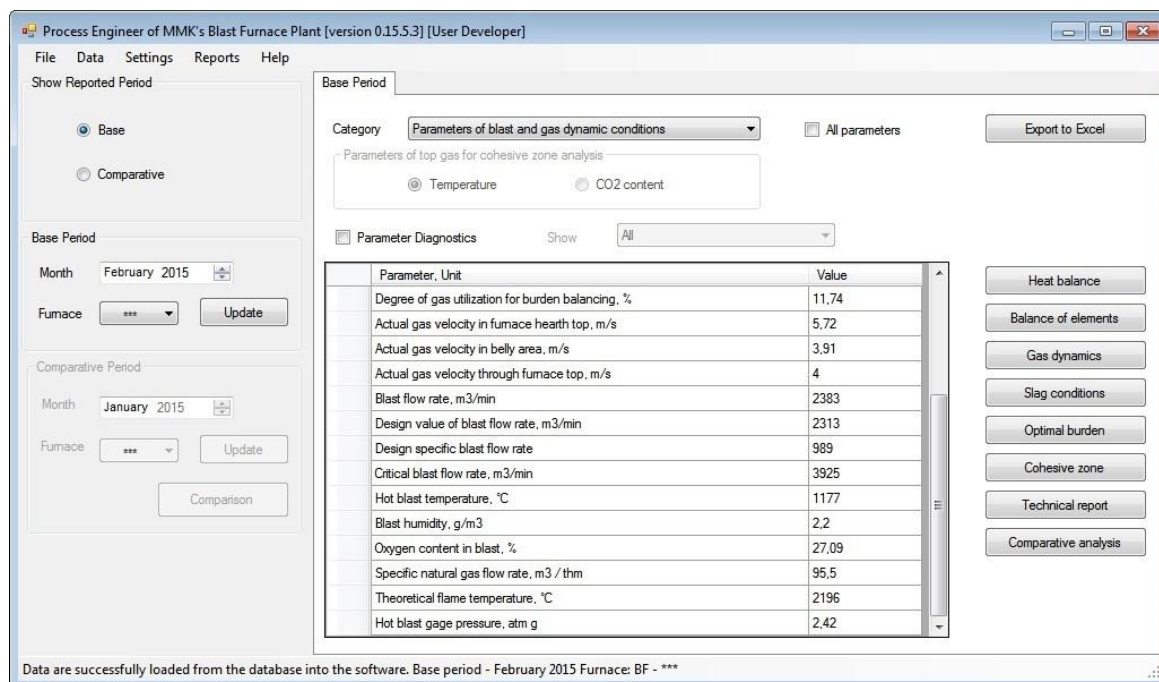


Figure 3. Main window of software complex for BF Process Engineer's Automated Workstation.

For easy and quick perception of process situations and blast furnace performance parameter trends in the base and comparative periods the user can see the data under separate categories: "Operating Parameters", "Furnace Structural Dimensions", "Coke Properties", "Burden Parameters and Consumption", "Blast Parameters", "Furnace Top Gas", "Liquid Molten Products: Iron", "Liquid Molten Products: Slag", "Heat Balance", "Fe Balance", "S Balance", "Zn Balance", "Ti Balance", "CaO Balance", "Cr Balance", "First Slag", "Final Slag"; "Gas Dynamics".

Apart from providing data for the current analysis of the reported parameters and evaluation of the production situations, the BF Process Engineer's Automated Workstation also enables to solve a number of process tasks related to control of heat, gas dynamic and slag conditions of blast furnace smelting as well as to calculate the optimal burden composition.

5. Conclusions

Using modern engineering technologies and software tools [6–8], a system for analysis and prediction of production situations in the blast furnace plant of Magnitogorsk Iron and Steel Works was developed and put into pilot industrial operation. This system provides the operators with a modern tool for online analysis of reported performance parameters [9, 10]. Application of the developed system will allow the operators to analyze online production situations in the blast furnace plant and to solve problems related to control of blast furnace smelting technology, which eventually results in increasing technical and economic performance parameters of blast furnace production.

6. Acknowledgements

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7. References

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